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# High-temperature weld root corrosion inspection

Time-of-flight diffraction on carbon steel pipe welds at 200 °C

## 1. Scope of the Technical Note

Ultrasonic time-of-flight diffraction (TOFD) is a popular method widely used in petrochemical, energy and other industries for the in-service detection and characterisation of welds defects such as root corrosion, porosity, inclusions, and cracks. However, with increasing demand for on-stream measurements, conventional TOFD is limited due to the temperature at which these probes can operate, often causing failure of the transducer, or causing noise in the wedges to mask the ultrasound signal.

Ionix high-temperature TOFD transducers, with integrated wedges, are suitable for weld inspections at continuous elevated temperatures up to 350 °C. Here, the transducers with integrated wedges are mounted on to a modified EddyFi Lyncs scanner for high-temperature encoding, with high-temperature couplant, connected to commercially available Mantis UT set, and a carbon steel pipe weld inspected at 200 °C for weld root corrosion.

**Highlights:**

- The full circumference of the pipe weld was inspected at 200 °C surface temperature
- Remaining ligament of the weld root was accurately determined within ±0.2 mm of the benchmark data taken with conventional TOFD at ambient temperature.
- Suitable resolution was achieved for accurate weld root evaluation at elevated temperature

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## 2. Methodology

A carbon steel pipe with a circumferential butt weld was inspected for weld root corrosion.

Table 1: Summary of the pipe asset

| Diameter | Material | Wall thickness | Weld cap | Weld defects |
|---|---|---|---|---|
| 8" NPS | Carbon steel | Sch 120<br>Nominal wt<br>= 18 mm | ~50 mm wide | • Weld root corrosion known from benchmark TOFD at ambient |

An EddyFi Lyncs scanner was modified with magnetic wheels, compatible tool posts and encoder for high-temperature operation (up to 350 °C) (Figure 1) and connected to an EddyFi Mantis UT flaw detector set. A pair of Ionix HotSense, 5 MHz, 6mm diameter crystal HT TOFD probes with integrated 60 degree (at 200 °C) 10"-profiled wedges were fitted with compatible pins for the Lyncs HT scanner, and coupled with Echo Ultrasonics Echo 6HT pumpable couplant (with an auto-ignition temperature of 421 °C) through the couplant channels on a continuous drip feed from a pump.

*Figure 1: Photograph of the modified Lyncs scanner with probes for high temperature shown on a pipe section.*

The probes were connected to the UT set via 5 m, dual lemo 00 to lemo 00 high-temperature cables. The pipe surface temperature was monitored by a K-type thermocouple as 200 °C after the probes and scanner were mounted and allowed to stabilise for 5 mins.

The A-scan range was set capturing the lateral wave, backwall reflection and mode converted wave on the pipe away from the weld, and a PCS set of 56 mm for the wedge angle of 60° with a velocity of 5745 m/s for 200 °C in steel, according to Figure 2 – ISO 16809 for carbon steel.

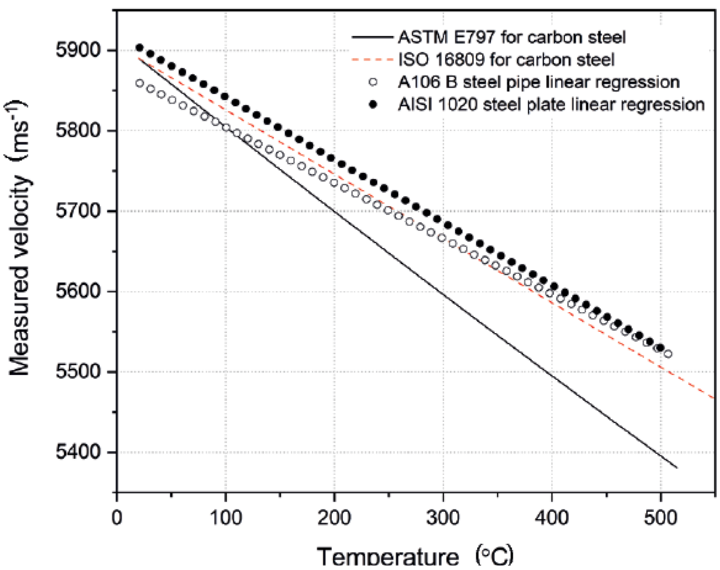


*Figure 2: Plot of longitudinal wave velocity according to ASTM E797 (line) and ISO 16809 (dashed) applied to carbon steel; and A106B steek pipe linear regression (circle) and AISI 1020 low-carbon steel linear regression (dot) from doi 10.1784/insi.2021.63.11.641*

The pulser voltage was set to the default 200 V with a 100 ns pulse length. Receiver filters used were low pass 10 MHz. B-scans were produced for the circumference, scanning both halves from 12 o-clock position in 1 mm steps, after all loose scale and debris was removed with a steel wire brush (Figure 3).

*Figure 3: Photograph of the pipe weld inspected at 200 °C.*

## 3. Results

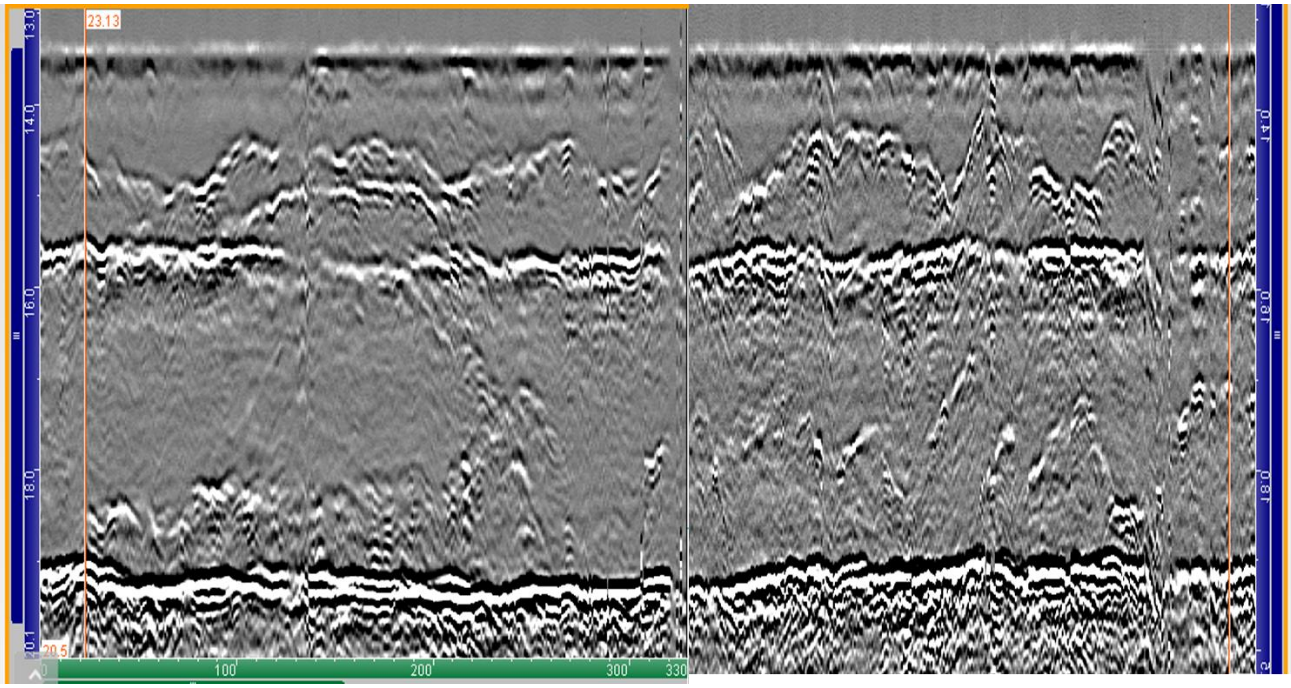


Figure 4: *Two Mantis (EddyFi) B-scan representations (lateral wave straightened) of each half, combined together, collected with 5 MHz, 6 mm dia. transducers with 60-degree integrated 10" profiled wedge from a 8" NPS diameter pipe butt weld at a surface temperature of 200 °C with Echo6HT couplant. Reference gain of 54 dB.*

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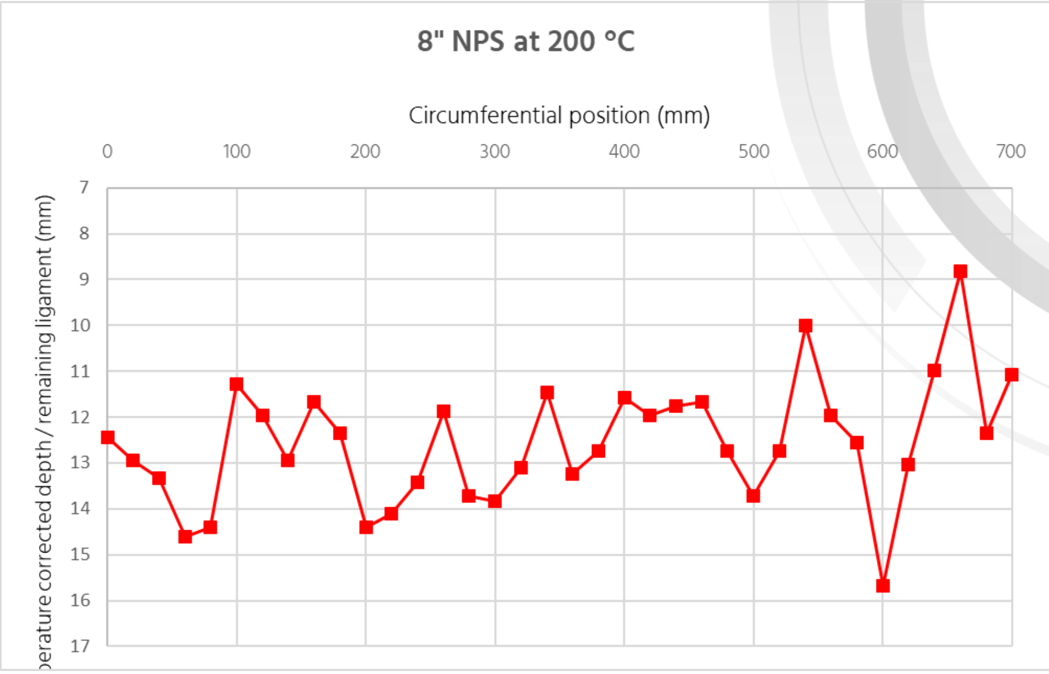


Figure 5: *Plot of remaining ligament depth (mm) around the circumferential position at 200 °C*

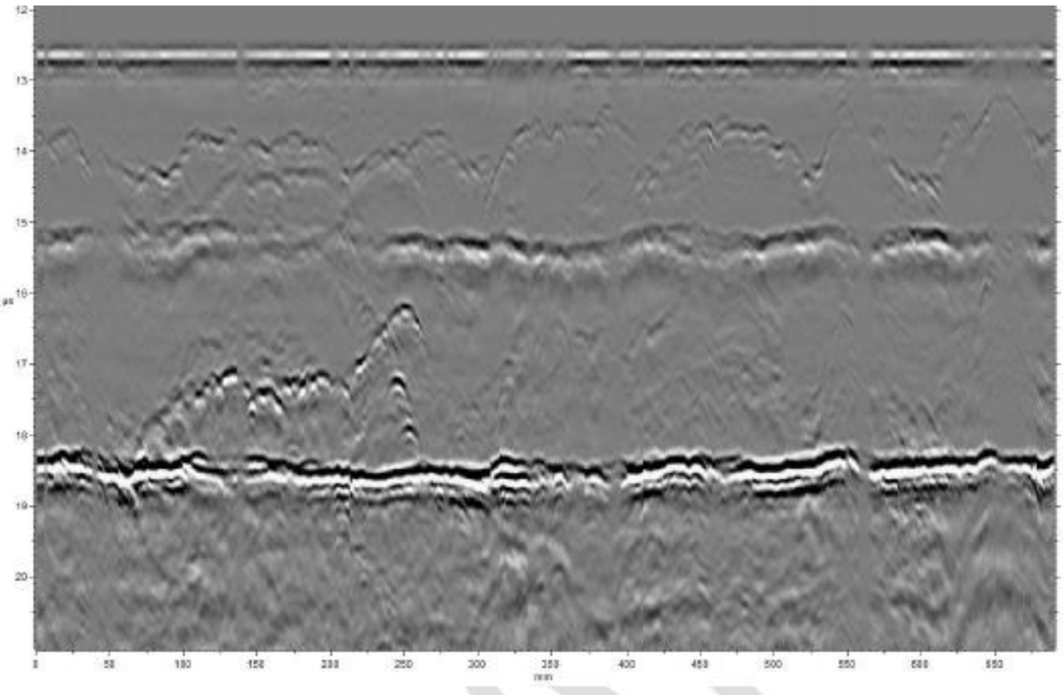

Figure 6: *Benchmark B-scan (lateral wave straightened) collected on the same butt weld with conventional 5 MHz, 3 mm diameter TOFD probes, with 60 degree wedges at ambient temperature.*

The B-scan collected at 200 °C (Figure 4) shows clear detection of the backwall and weld root corrosion. Remaining ligament analysis is plotted in Figure 5 and shows that the overall minimum ligament sizing is within ±0.2 mm of the benchmark TOFD data in Figure 6.

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## 4. Conclusions

Throughout the circumferential weld inspection at 200 °C

- Coupling is maintained with good lateral wave signal to noise
- Acceptable accuracy of the remaining ligament is achieved even at elevated temperature.
- High-temperature TOFD is a suitable technique to determine wall loss due to weld root corrosion.

| HotSense Technical Note | |
|---|---|
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